APPENDIX E

TITAN

Structural Loads

Limit load factors are given in Table E-1 for the Titan II launch vehicle. These load factors are for preliminary use and will be updated as the program develops.

Table E-1
TITAN II
Limit Load Factor (G)
at Spacecraft C.G.
1350-2270 kg (3000-5000 lb) Payload

Event	Vehicle			
	Titan II G	Titan II G/ Third Stage	Titan II S/ Enhanced ACS	Titan II S/ Third Stage
Liftoff				
- Axial	3.0 to -0.5	2.5 to -1.0	2.1 to 0	2.1 to 0
- Lateral	± 3.0	± 3.5	± 1.0	± 1.0
Maximum Airloads				
- Axial	3.0 to 1.0	**	**	**
- Lateral	± 2.5			
Stage I Burnout				
- Axial	8.5 to 3.0	7.5 to 3.0	8.5 to 3.0	7.5 to 3.0
- Lateral	± 2.5	± 3.5	± 3.5	± 3.5
Stage II Shutdown				
- Axial*	10.0 to 1.0	6.5 to 2.5	8.5 to 1.0	6.5 to 2.5
- Lateral	± 1.0	± 3.0	± 1.0	± 3.0

* Function of spacecraft weight, assume 2270 kg (5000-lb) spacecraft and may be reduced by Stage-II reduced thrust modification.

** Enveloped by other load events

Acoustics

The qualification and acceptance test levels are given in Tables E-2 and E-3 for various payload fairings (PLF).

Mechanical Shock

The qualification and acceptance shock test levels representing the maximum expected Titan II induced shocks at the payload interface are given in Table E-4.

Table E-2
TITAN IIG
Acoustic Test Levels
with Acoustic Blankets
(Inside Payload Fairing)

One-Third Octave Center Frequency (Hz)	Noise Level (dB) re: .00002 Pa	
	Qualification	Acceptance
25	110	107
32	112.5	109.5
40	118	115
50	117	114
63	119.5	116.5
80	124	121
100	125	122
125	126.5	123.5
160	126	123
200	126	123
250	127	124
315	128.5	125.5
400	128.5	125.5
500	128.5	125.5
630	129	126
800	128.5	125.5
1000	126.5	123.5
1250	127.5	124.5
1600	126	123
2000	123.5	120.5
2500	122	119
3150	120	117
4000	115	112
5000	112.5	109.5
6300	109.5	106.5
8000	105	102
10000	102.5	99.5
Overall	139	136

Table E-3
TITAN IIS
Acoustic Test Levels
with Acoustic Blankets
(Inside Payload Fairing)

One-Third Octave Center Frequency (Hz)	Noise Level (dB) re: .00002 Pa	
	Qualification	Acceptance
25	116	113
32	119	116
40	120.5	117.5
50	123	120
63	125.5	122.5
80	127.5	124.5
100	128	125
125	128.5	125.5
160	129	126
200	129	126
250	129.5	126.5
315	129.5	126.5
400	129.5	126.5
500	129.5	126.5
630	129.5	126.5
800	128	125
1000	125.5	122.5
1250	124.5	121.5
1600	121.5	118.5
2000	121	118
2500	120	117
3150	120	117
4000	116.5	113.5
5000	115.5	112.5
6300	113.5	110.5
8000	110	107
10000	107	104
Overall	140	137

Table E-4
TITAN II
Shock at Payload Interface
Q=10

Frequency (Hz)	Shock Response Spectrum (G)	
	Qualification	Acceptance
100 100-500 500-1250 1250-5000 5000	100 +3.9 dB/oct 280 -4.9 dB/oct 90	70 +3.9 dB/oct 200 -4.9 dB/oct 65

Structural Loads

Limit load factors are given in Table E-5 for the Titan III commercial launch vehicle. These load factors are for preliminary use and will be updated as the program develops.

Table E-5
TITAN III
Limit Load Factors
at Spacecraft C.G.

Loading Condition	Limit Load Factor (G)	
	Axial	Lateral
Maximum Lateral	2.75	± 1.8
Maximum Axial	+5.4 / -1.3	± 0.5

Note: Assumes use of water suppression system at lift-off. Non-steady-state part of loads contains a dynamic uncertainty factor of 1.5.

In general, it is recommended that the first mode frequencies for the fixed base payload, including adapter, be greater than 15 Hz lateral and 26 Hz axial.

Acoustics

Typical acoustic levels are given in Table E-6 for the Titan III vehicle. The levels should be verified with the Titan III program office.

Spacecraft Random Vibration

The maximum expected random vibration flight levels (limit levels) at the spacecraft interface are given in Table E-7

Table E-6
TITAN III
Acoustic Test Levels
Inside Payload Fairing
(Assumes 50% Payload Fill)

One-Third Octave Center Frequency (Hz)	Noise Level (dB) re: .00002 Pa	
	Qualification	Acceptance
25	130	127
32	131	128
40	132.5	129.5
50	133	130
63	134	131
80	134.5	131.5
100	135	132
125	135	132
160	135	132
200	134.5	131.5
250	133.5	130.5
315	132.5	129.5
400	131.5	128.5
500	129.5	126.5
630	128	125
800	126	123
1000	124	121
1250	122	119
1600	120	117
2000	118	115
2500	116	113
3150	114	111
4000	112	109
5000	110	107
6300	108	105
8000	106	103
10000	104	101
Overall	145	142

Table E-7
TITAN III
Spacecraft Random Vibration
Limit Levels

Frequency (Hz)	ASD Level (G^2/Hz)
20	.002
20-160	+5.0 dB/oct
160-800	.018
800-2000	-6.0 dB/oct
2000	.00065
Overall	4.2 G_{rms}

Mechanical Shock

The maximum expected launch vehicle induced mechanical shock at the spacecraft interface is given in Table E-8 for a V-band separation system, and in Figure E-1 for the Expanding Tube Separation System (ETSS).

Table E-8
TITAN III
Maximum Expected Shock Spectrum
(V-Band Separation System)
Q=10

Frequency (Hz)	Shock Response Spectrum (G)	
	Qualification	Acceptance
160	140	100
160-1250	+10.9 dB/oct	+10.9 dB/oct
1250-10000	5740	4100

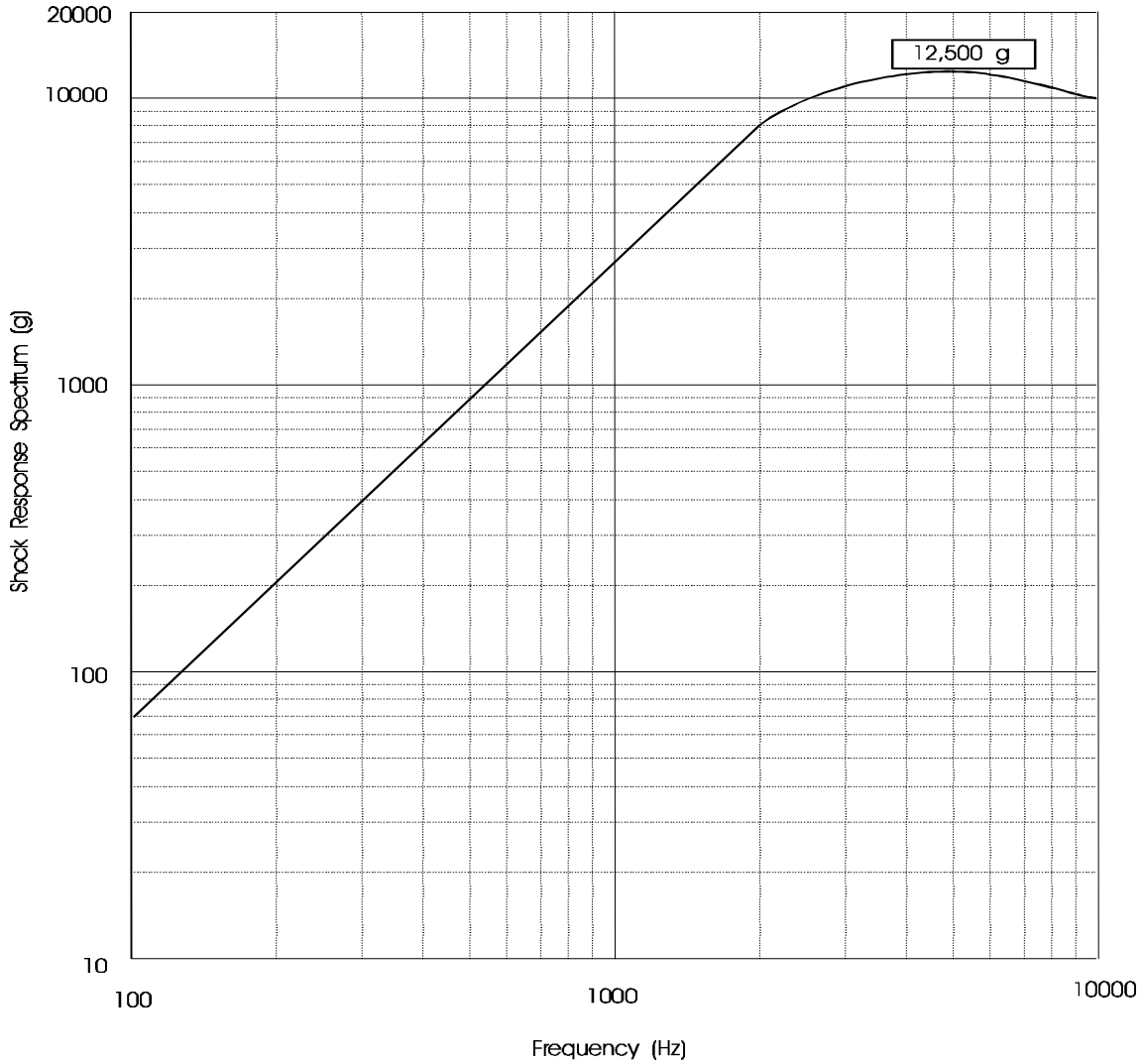

Figure E-1 Titan III Maximum Expected Shock Response at Payload Interface for the Expanding Tube Separation System (ETSS)

Structural Loads

The spacecraft response is a function of its weight, stiffness, and lateral/axial coupling as well as the launch vehicle/booster configuration. Limit load factors are provided in Tables E-9 through E-12 for preliminary evaluation of spacecraft primary structure utilizing various TITAN IV configurations and spacecraft weights. For these limit loads, the spacecraft center of gravity is assumed to be located approximately 30-40% of the spacecraft length from the spacecraft/launch vehicle interface. Transient loads analyses must be performed during the development of the spacecraft to provide detailed member loads and responses required for complete design and evaluation of the structure including interface loads and loss-of-clearance.

Significant spacecraft lateral excitation can occur in the 4-10 Hz range due to liftoff and maximum airloads, and significant axial excitation can occur in the 17-24 Hz range due to Stage I Shutdown thrust oscillations.

To minimize the interaction between low frequency lateral modes and the launch vehicle control system performance, the first lateral mode should be above 2.5 Hz.

Acoustics

The qualification and acceptance acoustic levels are given in Table E-10 for the Titan IV vehicle. These represent the levels for an empty payload fairing and should be adjusted by a fill-factor. The expected levels should be confirmed with the Titan IV program office since they are dependent on the payload fairing length, the location and number of vents and access doors, the amount and location of acoustic blankets, and spacecraft volume and acoustic properties.

Mechanical Shock

The primary sources of pyroshock during a launch occur at SRM separation, Stage I/II separation, PLF separation, Upper Stage separation, if applicable, and payload separation. The last three are the only ones of significance to the spacecraft. The maximum expected launch vehicle induced shocks at the spacecraft interface for the Titan IV/ Centaur and Titan IV/ NUS (no upper stage), configurations are given in Figures E-2 and E-3 respectively.

The maximum allowable spacecraft produced shock response levels for Centaur 8- and 22-hardpoint configurations are given in Figures E-4 and E-5 respectively

Figure E-6 gives the maximum IUS induced and maximum spacecraft induced shock levels at the IUS-spacecraft interface.

Table E-9
TITAN IV
Limit Load Factors
at Spacecraft C.G.
Centaur Configuration
4,500-6,800 kg (10,000-15,000 lb) Spacecraft

Event	Load Factor			
	Direction	Static	Dynamic	Total
Lateral (liftoff and maximum airloads)	Axial	1.0/2.0	± 1.0	0.0/3.0
	Lateral	0.0	± 2.5	± 2.5
	Torsion	0.0	± 0.02	± 0.02
	Rotation	0.0	± 0.03	± 0.03
Axial (stage I and II shutdown)	Axial	0.0/4.0	± 2.0	-2.0/6.0
	Lateral	0.0	± 1.5	± 1.5
	Torsion	0.0	± 0.02	± 0.02
Torsion (FBR release)	Axial	2.0	0.0	2.0
	Torsion	0.0	± 0.04	± 0.04

Notes:
1. Load factors are limit values at the spacecraft center of gravity in g for the axial and lateral values and g/in. for torsion and rotation.
2. Lateral and rotational load factors are RSS values which may be applied at any azimuth.
3. Load factors are for major structural members and do not include margin for component design.
4. Load factors for lateral envelopes OSS and no-OSS liftoff cases.

Table E-10
TITAN IV
Limit Load Factors
at Spacecraft C.G.
IUS Configuration
2,270-3,630 kg (5,000-8,000 lb) Spacecraft

Event	Load Factor			
	Direction	Static	Dynamic	Total
Lateral (liftoff and maximum airloads)	Axial	1.0/2.0	± 1.0	0.0/3.0
	Lateral	0.0	± 3.0	± 3.0
	Torsion	0.0	± 0.03	± 0.03
	Rotation	0.0	± 0.02	± 0.02
Axial (stage I and II shutdown)	Axial	0.0/4.0	± 2.0	-2.0/6.0
	Lateral	0.0	± 1.5	± 1.5
	Torsion	0.0	± 0.02	± 0.02

Notes:
1. Load factors are limit values at the spacecraft center of gravity in g for the axial and lateral values and g/in. for torsion and rotation.
2. Lateral and rotational load factors are RSS values which may be applied at any azimuth.
3. Load factors are for major structural members and do not include margin for component design.
4. Load factors for lateral envelopes OSS and no-OSS liftoff cases.

Table E-11
TITAN IV
Limit Load Factors
at Spacecraft C.G.
NUS Configuration
9,080-13,620 kg (20,000-30,000 lb Spacecraft)

Event	Load Factor			
	Direction	Static	Dynamic	Total
Lateral (liftoff and maximum airloads)	Axial	1.0/2.0	± 1.0	0.0/3.0
	Lateral	0.0	±2.5	± 2.5
	Torsion	0.0	± 0.03	± 0.03
	Rotation	0.0	± 0.03	± 0.03
Axial (stage I and II shutdown)	Axial	0.0/4.0	± 2.0	-2.0/6.0
	Lateral	0.0	± 1.5	± 1.5
	Torsion	0.0	± 0.02	± 0.02
Torsion (FBR release)	Axial	2.0	0.0	2.0
	Torsion	0.0	± 0.01	± 0.01

Notes:
1. Load factors are limit values at the spacecraft center of gravity in g for the axial and lateral values and g/in. for torsion and rotation.
2. Lateral and rotational load factors are RSS values which may be applied at any azimuth.
3. Load factors are for major structural members and do not include margin for component design.
4. Load factors for lateral envelopes OSS and no-OSS liftoff cases.

Table E-12
TITAN IV
Limit Load Factors
at Spacecraft C.G.
NUS Configuration
13,020-18,160 kg (30,000-40,000 lb) Spacecraft

Event	Load Factor			
	Direction	Static	Dynamic	Total
Lateral (liftoff and maximum airloads)	Axial	1.0/2.0	± 1.0	0.0/3.0
	Lateral	0.0	±2.0	± 2.0
	Torsion	0.0	± 0.02	± 0.02
	Rotation	0.0	± 0.02	± 0.02
Axial (stage I and II shutdown)	Axial	0.0/4.0	± 2.0	-2.0/6.0
	Lateral	0.0	± 1.0	± 1.0
	Torsion	0.0	± 0.01	± 0.01

Notes:
1. Load factors are limit values at the spacecraft center of gravity in g for the axial and lateral values and g/in. for torsion and rotation.
2. Lateral and rotational load factors are RSS values which may be applied at any azimuth.
3. Load factors are for major structural members and do not include margin for component design.
4. Load factors for lateral envelopes OSS and no-OSS liftoff cases.

Table E-13
Titan IV
Acoustic Test Levels
(Inside Empty Payload Fairing,
with Acoustic Blankets)

One-Third Octave Center Frequency (Hz)	Noise Level (dB) re: .00002 Pa	
	Qualification	Acceptance
25	126.0	123.0
32	128.0	125.0
40	129.5	126.5
50	130.0	127.0
63	131.0	128.0
80	131.5	128.5
100	132.0	129.0
125	132.0	129.0
160	132.0	129.0
200	131.5	128.5
250	131.0	128.0
315	130/5	127.5
400	129.5	126.5
500	128.5	125.5
630	127.5	124.5
800	126.0	123.0
1000	124.5	121.5
1250	123.0	120.0
1600	121.0	118.0
2000	119.5	116.5
2500	118.0	115.0
3150	116.0	113.0
4000	114.5	111.5
5000	112.5	109.5
6300	110.5	107.5
8000	109.0	106.0
10000	107.0	104.0
Overall	142	139

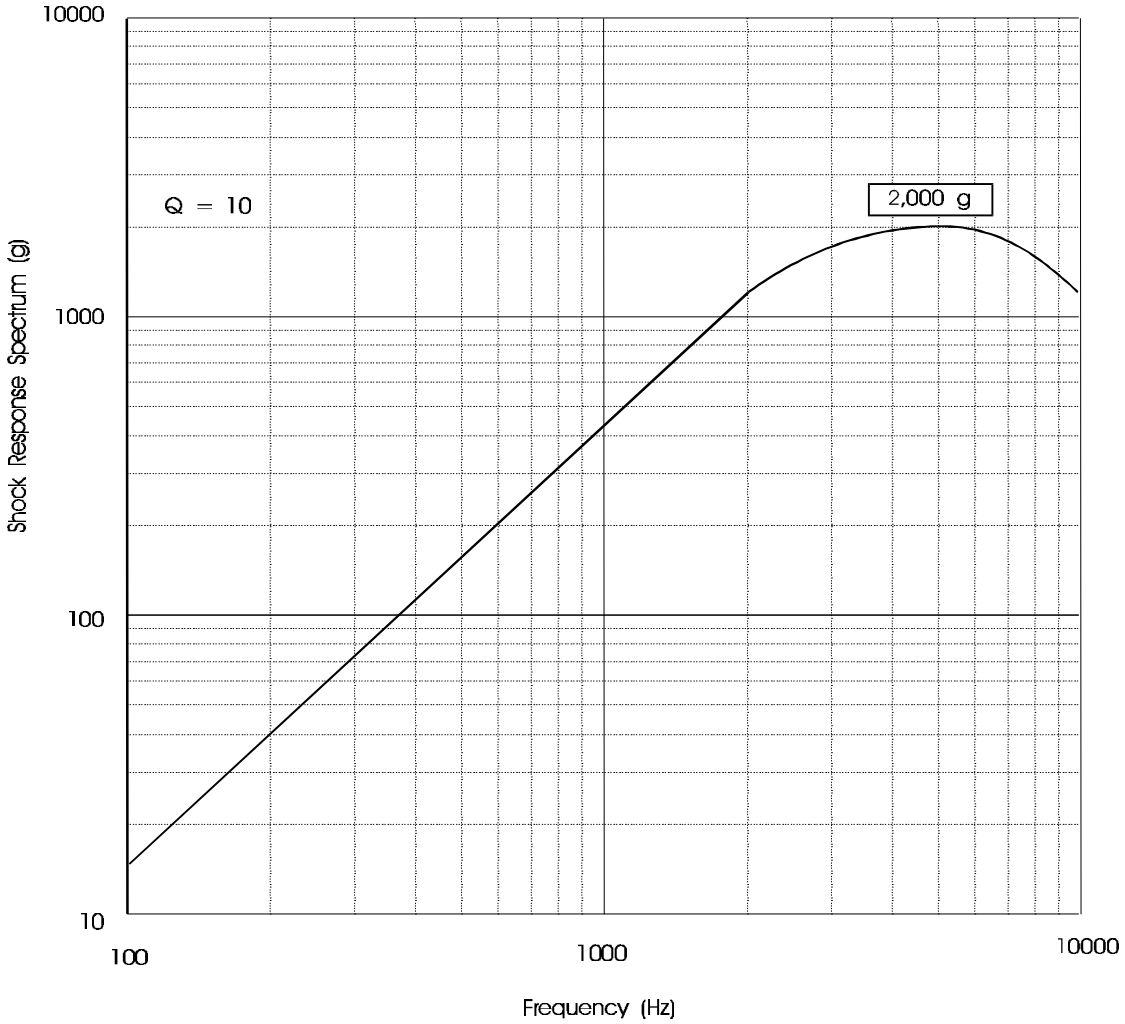

Figure E-2 Maximum Shock Response at the Centaur/Spacecraft Interface Produced by either the TITAN IV or the Centaur (8 or 22 Hardpoint Interface)

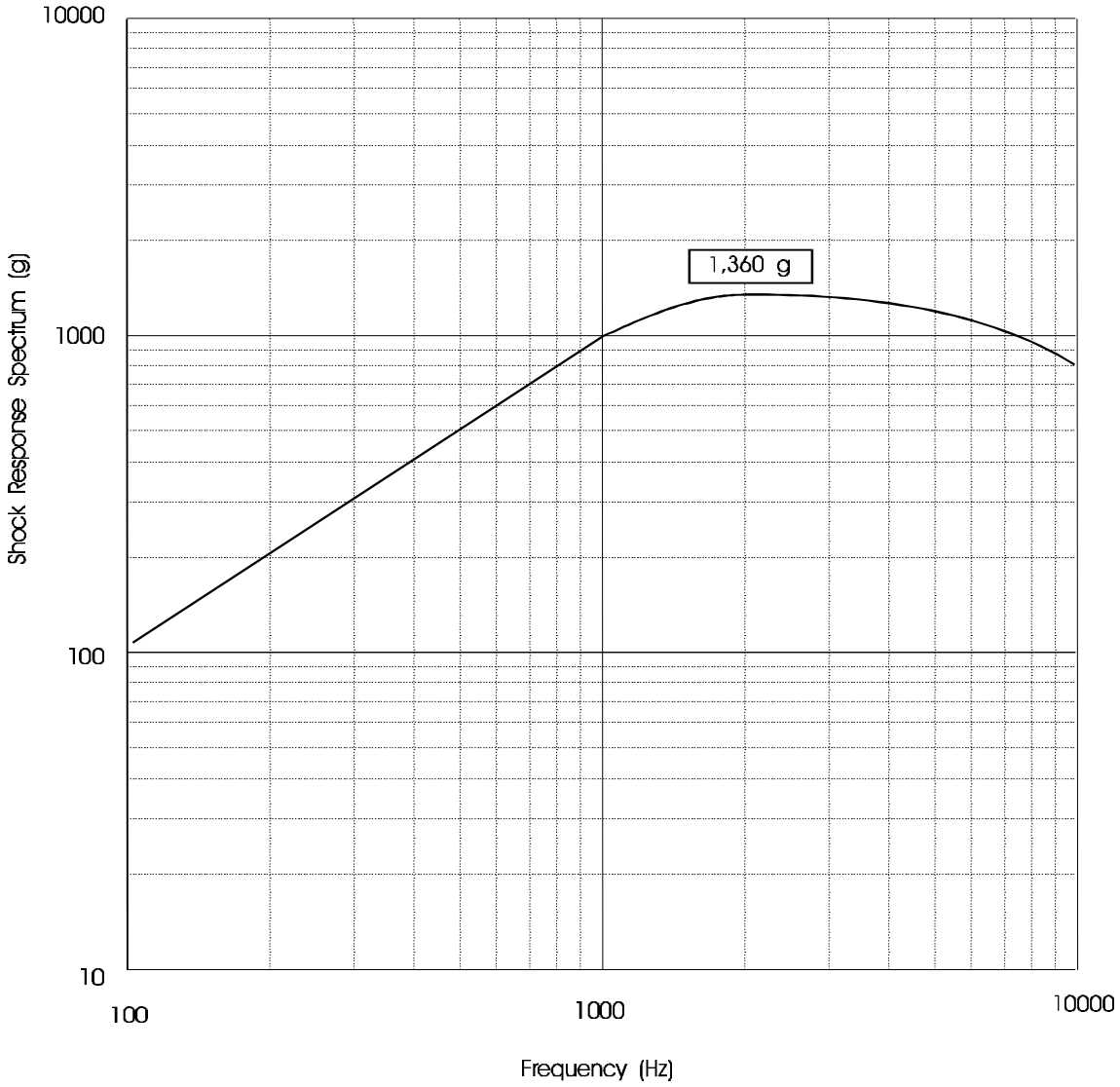

Figure E-3 Maximum Allowable Shock Response at Launch Vehicle/ Spacecraft Interface (VS 163) Produced by the TITAN IV or the Spacecraft for the NUS Configuration

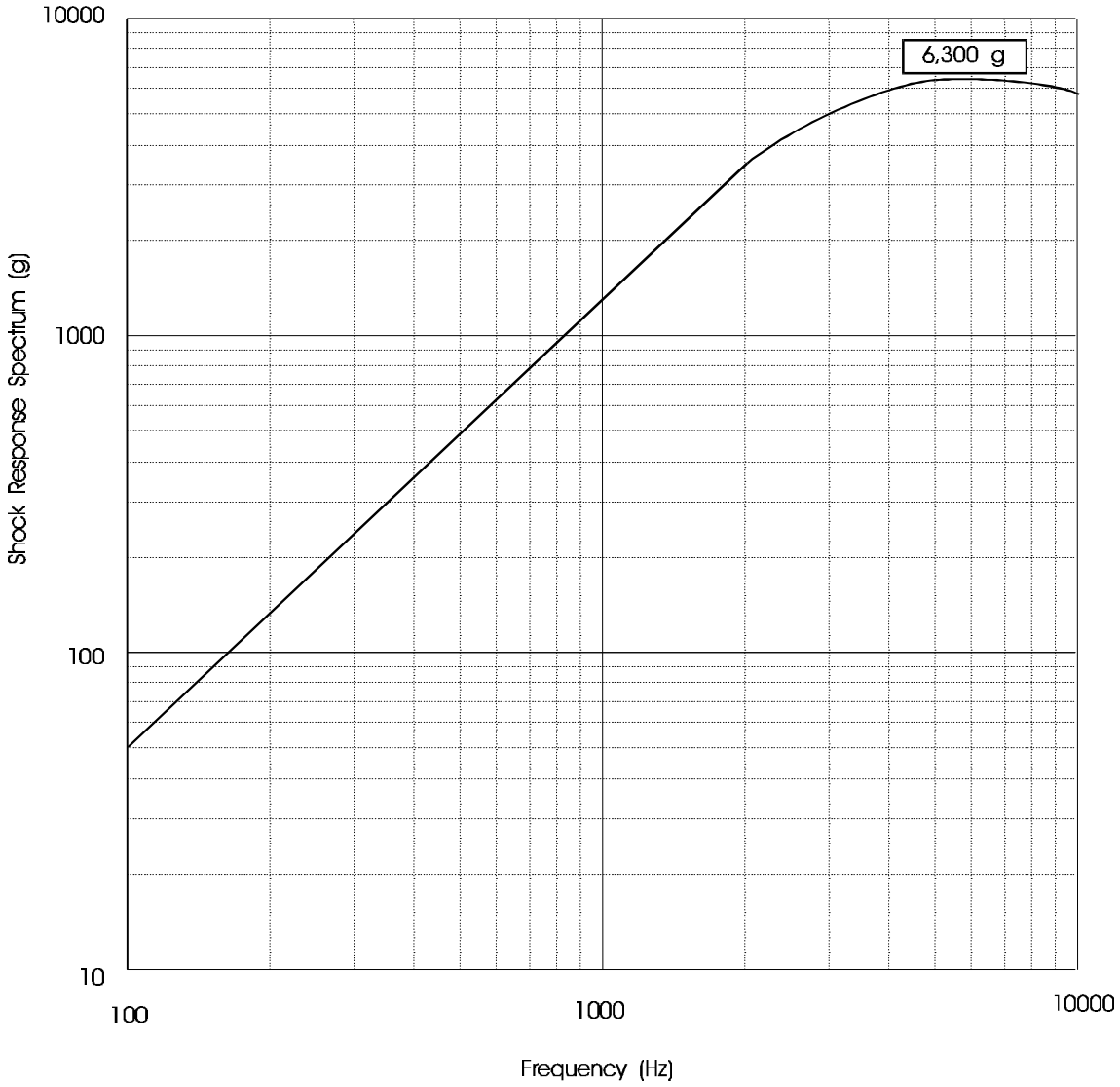

Figure E-4 Maximum Allowable Spacecraft Produced Interface Shock for Centaur Configuration (8- Hardpoint)

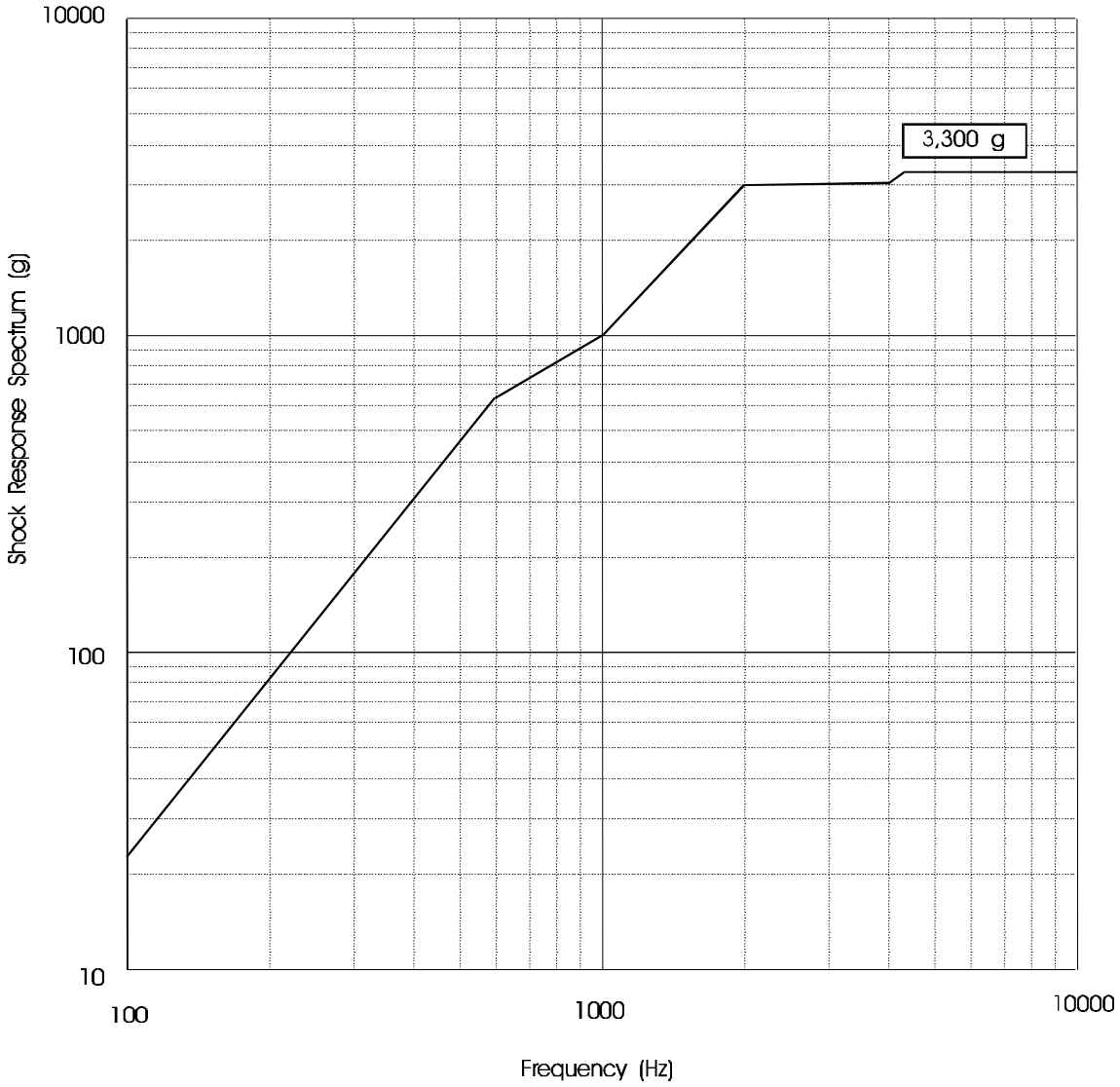

Figure E-5 Maximum Allowable Spacecraft Produced Interface Shock for Centaur Configuration (22- Hardpoint)

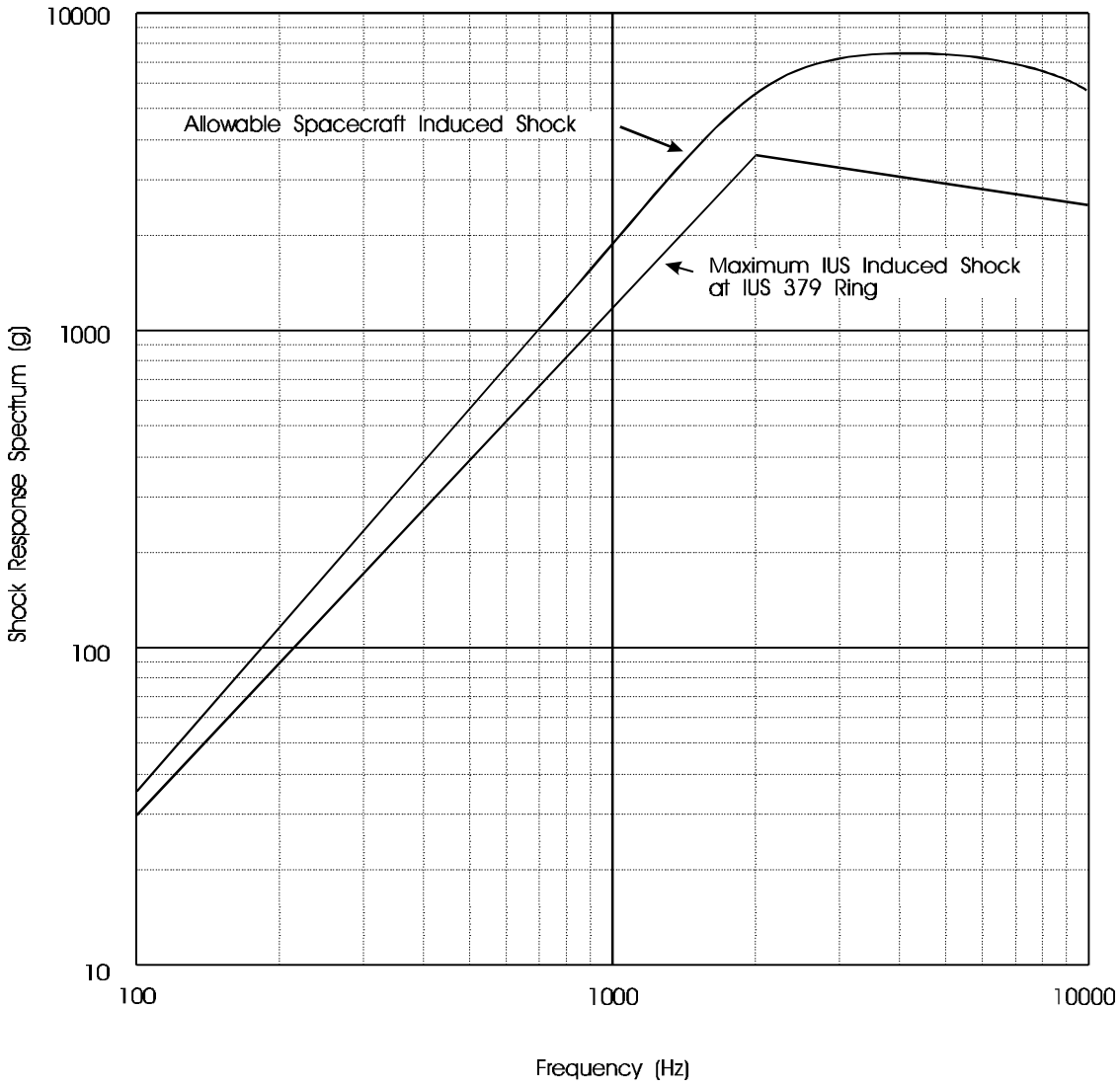

Figure E-6 Maximum IUS Induced and Maximum Allowable Spacecraft Induced Shock Levels at IUS-Spacecraft Interface